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#1

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February 18, 1997

Contract Officers
National Institutes of Health
National Institute of Neurological Disorders and Stroke
Federal Building, Room 901
7550 Wisconsin Ave., MSC 9190
Bethesda, Maryland 20892-9190

Subject: Contract No. NO1-NS-6-2352

Dear Drs. Schmidt and Heetderks:

I have just received word that my first quarterly report is late. Please accept my apologies for this oversight. I have not as yet received documentation from my business office on the proper schedule and format of these reports. However, I am pleased to report that good progress has been made on the project. In this report I will include progress up to the current date (2/18/97), even though it is well past December, 30, the official end of the quarter.

Upon receiving word in early October, 1996, that this contract would be awarded, I convened a telephone conference with my two subcontractors: Miguel Nicolelis at Duke University and Harvey Wiggins of Spectrum Scientific (now Plexon Inc.) in Dallas. We devised the following three-prong strategy, consistent with that outlined in our original proposal:

1- At Duke, Dr. Nicolelis would begin his work by assessing the prospects for long term recording of motor cortical neural ensemble activity in the behaving monkey cortex. In December, he implanted multiple microwire arrays in the arm areas of the MI and SI cortical regions of an owl monkey. Since then he has been recording these neuronal

This QPR is being sent to you before it has been reviewed by the staff of the Neural Prosthesis Program.

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ensembles during a trained arm reaching task. He has been able to identify and characterize both somatosensory and motor properties in these neurons individually, and at the population level. Further, he has continued to record from the cortices of monkeys implanted more than a year ago.

2- At Spectrum Scientific, first efforts have been directed toward preparing a Windows NT version of their MNAP system for multi-channel neural spike recording and discrimination. This will pave the path for development of a real-time interface capable of rapidly translating input neural ensemble information into the proper codes for output control of computer driven motion systems. Good progress has been made in this effort.

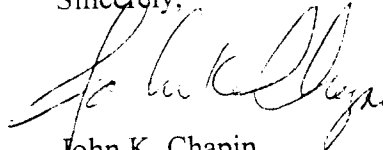
3- In my lab, I chose to focus on development of a working neuroprosthetic system in the rat model. This involved designing and building an electronic hardware a circuit capable of taking input from 32 channels of TTL voltage pulses from the Spectrum Scientific apparatus and translateing them into a single analog voltage for controlling movement of a robot arm. This circuit spatially integrates across the 32 spike channels using trimming potentiometers to adjust the input strength each channel according to a statistically defined weighting system. It then temporally integrates this signal according to an adjustable time constant, and finally low pass-filters it. We also built a behavioral training device, which allowed an animal to move a "robot arm" carrying a small water reward to its mouth by using its right arm to move a manipulandum. This involved mounting an angular transducer to the manipulandum, yielding an analog voltage which was fed into a physiograph pen-motor system. The pen motor was adapted to move the robot arm between a water source and a slot in the rat's enclosure, allowing the rat to drink the water. In January we trained two water deprived rats to use their forelimbs to use the manipulandum to move the robot arm from the water source to their mouths. The rats learned this task readily. We then surgically implanted microwire arrays in the M1 cortex and VL thalamus of one of the rats. After about 1 week, this animal was placed in the recording chamber and again allowed to get its water reward by using the manipulandum to move the robot arm. Out of 24 microwires implanted in this rat, we obtained a total of 36 good quality discriminable units. Nearly all of these units were active in correlation with the manipulandum movement task, in particular when the animal reached to grasp the manipulandum from a resting position. After storing these data on the computer we performed a principal component analysis (PCA) and found that the time-integrated population vector of these units' activity, as weighted using the first principal component (PC1), matched rather well the overall movement associated with the manipulandum movement, including especially the movement to place the paw on the manipulandum. We therefore used the principal component weightings to adjust the potentiometers on the newly built hardware interface board, such that its voltage output closely approximated the population vector defined by PC1. This output was then fed into the physiograph pen-motor system controlling the robot arm, and its normal input through the manipulandum was switched off. After adjusting the amplitude of this system, the rat was able to move the robot arm through its neuronal ensemble activity, as translated through the interface board, rather than through direct

movement of the manipulandum. Using multi-single neuron activity, however, the movement of this robot arm was rather jerky. We then set the discriminators to record the combined activity of 2-4 local units, rather than single units. The appropriately weighted PC1 population vector from these recordings provided a better match to the overall limb movement than did the single neurons. Furthermore, when this PC1 population vector was translated through the interface board, it created a smoother movement of the robot arm. In this case, the robot arm was able to fetch the water with high reliability when the rat moved its arm in the proper way

Our plan for the next quarter is to continue the above described studies. The success of the hardware interface in the rat suggests that it may be profitable to add more channels to the current interface, and to also make another such interface for the monkey. It may be at least a year before a substantially better interface can be implemented on the computer. Spectrum Scientific must first complete its Windows NT version before it can realistically address the interface problem full time. In addition, we feel it is essential for them to soon address the automatic spike detection problem. The rat studies in this lab will continue to investigate different questions surrounding the neural control of robot arms, such as: 1) the number of single or multi-units required to achieve a given degree of accuracy, 2) the ability to dissociate overt movement from the neural command, 3) the ability to encode multiple dimensions of information from the recorded neuronal ensembles, and 4) the spatio-temporal transformation algorithms which must be implemented in a future computer interface to optimize the direct encoding of motor cortical (and thalamic) activity into robot arm movement.

Thank you again for your awarding of this contract to our group.

Sincerely,

A handwritten signature in dark ink, appearing to read "John K. Chapin", written in a cursive style.

John K. Chapin
Professor